SECTION 4
MAJOR ISSUES ADDRESSED IN THE REFORMULATION

Multiple issues were considered in the reformulation of river management alternatives for the RGCP based on input provided by stakeholders during the USIBWC consultation process (Table 2-3). Those issues were organized into the following four major categories and are discussed in subsequent sections:

- Water issues, including flow regime, water availability, allocation, and water delivery requirements;
- River configuration and sediment transport;
- Flood control in terms of its potential to support ecosystem restoration; and
- River restoration analysis.

4.1 WATER ISSUES

4.1.1 Relevance for the Reformulation

Low precipitation conditions prevalent in the Middle Rio Grande watershed severely restrict water availability in the RGCP. As all river water and agricultural return flows in the RGCP are fully allocated, water acquisition becomes a requirement for implementation of environmental measures for riparian corridor development, aquatic habitat diversification, and changes in flow regime. Such acquisition faces competing interests of municipal entities, making water acquisition a critical element in a river restoration program.

For nearly a century, flows along the RGCP have been tightly controlled by a series of upstream reservoirs which release water primarily to meet the needs of agricultural lands in New Mexico, Texas, and Mexico. As a result, water delivery needs control the flow regime along the RGCP and limit the type and extent of environmental measures that can be implemented.

4.1.2 Water Availability

Rio Grande water that flows through the RGCP originates from a watershed that covers the southern slopes of the Colorado Mountains and the mountain ranges of Northern New Mexico. The water, stored in Elephant Butte Reservoir, is used to irrigate the Rincon, Mesilla, El Paso, and Juarez Valleys.

Scheduled outflows from Elephant Butte Reservoir and Caballo Reservoir are based on average irrigation demands for years with a full water supply. The Elephant Butte Reservoir operations are based on average historic losses and evaporation rates.

Large-scale implementation of environmental measures necessitates periods of significant upstream storage. The Middle Rio Grande watershed is located in a semi arid climate that yields an average of less than 15 inches of rain per year (NMOSE 2003). Water availability in the Elephant Butte Reservoir has gone through several multi-year cycles, as illustrated in

Figure 4-1. Based on the historical record, low storage conditions at the reservoir were prevalent for nearly 4 decades, until significant water storage levels were recorded during the mid 1980s and 1990s (NMOSE 2001).

High rainfall over the past 2 decades, however, appears to be atypical based on the long-term rainfall record for New Mexico (Figure 4-2). The New Mexico Office of the State Engineer identified a trend toward drier conditions over the past 4 years (NMOSE 2003). As a result, storage conditions in Elephant Butte Reservoir are experiencing a sharp and steady decline (Figure 4-1).

4.1.3 Water Allocation

All river water and agricultural return flows along the RGCP have been fully allocated as part of the Rio Grande Project. This USBR project, in operation since 1905, furnishes irrigation water supply for about 178,000 acres of land in New Mexico and Texas, as well as electric power. Physical features of the Rio Grande Project include Elephant Butte and Caballo Dams, six diversion dams, and 457 miles of canals (USBR Website, *www.usbr.gov/dataweb/html/riogrande.html*).

Water allocation is a key consideration in a river restoration program because flow regime modifications, riparian corridor development, and aquatic habitat diversification are likely to require the acquisition of water rights. These acquisitions would require agreements with the EBID and EPCWID#1, and deal with potentially competing interests of municipal entities. Authorization changes are also likely for Rio Grande Project water use in habitat improvements.

The annual water release from Elephant Butte Dam averages 682,000 acre-feet. With normal yearly releases from Caballo Dam, coupled with return flows and rainfall runoff, water availability for agriculture is as follows:

- 494,979 acre-feet at EBID's headings in New Mexico;
- 376,862 acre-feet at EPCWID#1's headings in Texas, and
- 60,000 acre-feet at Mexico's Acequia Madre heading.

The original Rio Grande Project water allotment for irrigation district farmers was 3 acre-feet per acre per year (ft/yr). The water supply was allocated between the two irrigation districts based on the amount of land that each district had under irrigation. The USBR regularly evaluates hydrologic parameters including reservoir storage, snow pack, and forecast precipitation to establish water allocation for the primary irrigation season. The allocation is set at the beginning of the primary irrigation season and (if less than a full allocation) is adjusted during the irrigation season based on updated information. Each irrigation district determines water allotment for lands within its boundaries (USBR Website, *www.usbr.gov/dataweb/html/riogrande.html*).

Since the beginning of the Rio Grande Project, some of the land originally under irrigation has been removed from agricultural use and is no longer irrigated. This has allowed

Figure 4-1 Historic Storage Levels in Elephant Butte Reservoir (NMOSE 2001)

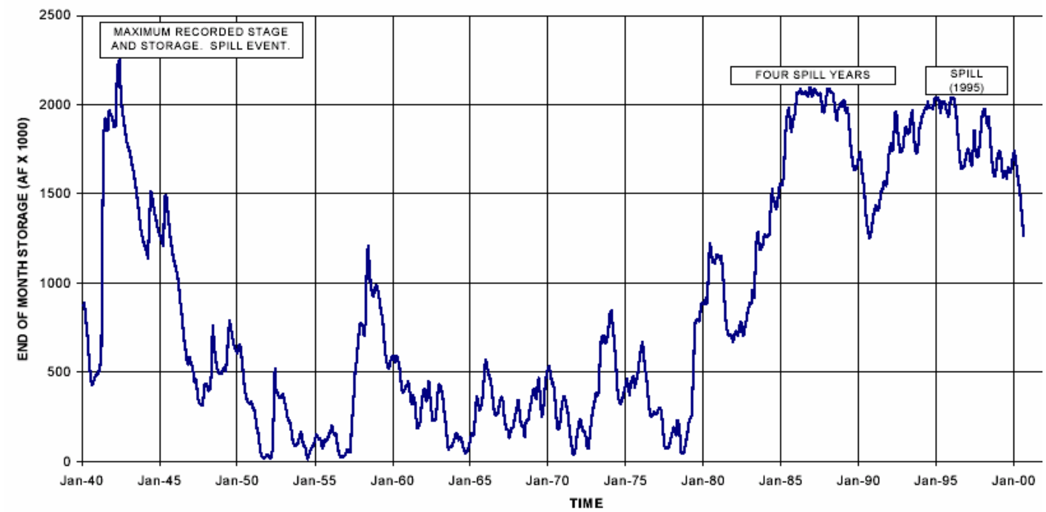
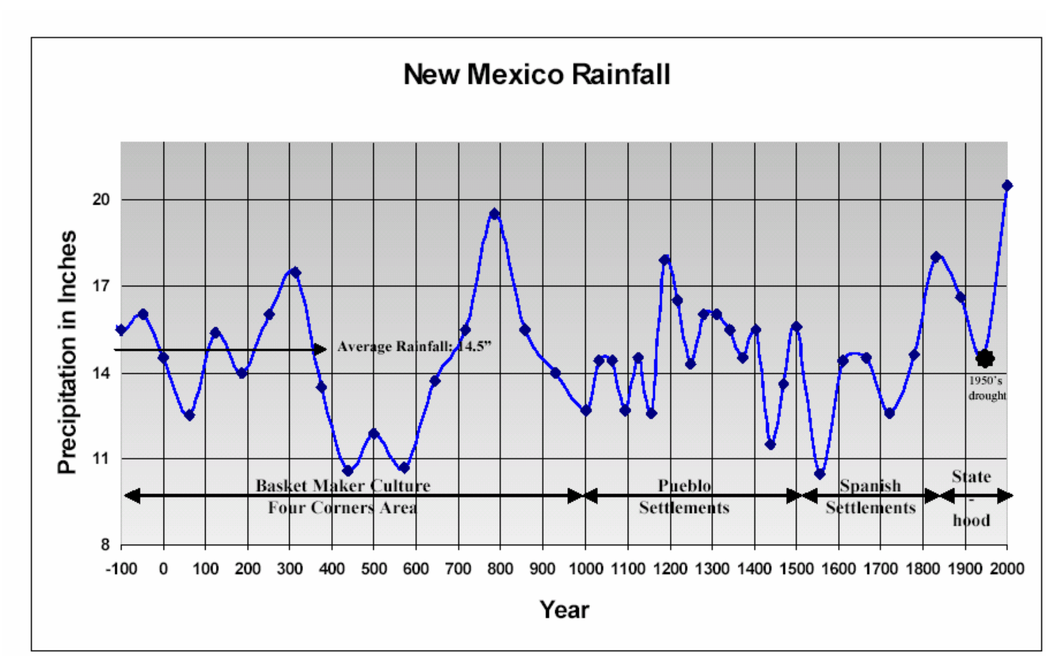


Figure 4-2 Long-Term Record of New Mexico Rainfall (NMOSE 2001)



additional water to be used on crops that require more than 3 ft/yr for adequate growth. Also, the Rio Grande Project water supply is not evenly distributed over a fixed number of acres. Farmers can fallow some fields to free up additional water for high use crops or lease their water to other farmers for their use. From 1979 through 1998 the average allotment for irrigated project lands in EPCWID#1 was 3.63 ft/yr (EPCWID#1 2000). In recent years, the allotment has been 4 ft/yr.

Potential water use in the RGCP floodway due to vegetation changes was presented in the March 2001 AFR. Relative to currently maintained mowed areas, the increase in water consumption was estimated at 1 ft/yr for managed no-mow zones, 1.5 ft/yr for riparian vegetation development, and up to 3.5 ft/yr for planting sites (Parsons 2001a).

4.1.4 Water Acquisition

The USIBWC does not have any water rights within the USBR's Rio Grande Project. River management alternatives were developed in the AFR considering water rights acquisition and water use reduction by salt cedar removal as the key methods to secure water for implementation of environmental measures (Parsons 2001a). In the reformulation, use of these two methods was re-evaluated along with two additional methods, ground water use and management of small magnitude, recurrent flood cycles. Options for water acquisition evaluated in the reformulation of alternatives are described below.

Water Rights Acquisition

Direct acquisition of water rights from the agricultural community was considered in the AFR as the primary method to secure water for environmental measures. Because direct water rights acquisition on a large scale would likely lead to decommissioning of agricultural lands, two options were considered in the reformulation of alternatives: water acquisition by supporting water conservation programs within irrigation districts, and water banking.

Support of water conservation by financing on-farm water conservation programs was identified as a viable strategy to secure water for use in environmental measures. On-farm irrigation methods currently in use, such as flood irrigation and center-pivot or side-roll sprinklers, have low efficiencies that can be increased from a typical range from 40 percent to 65 percent, to more than 85 percent with the use of drip irrigation systems and moisture-sensing devices (Wilson 2001).

Support of water conservation programs would not only be consistent with stated interests of the irrigation districts (EBID 1998; EPCWID#1 2000), but would also facilitate seeking funds from high-priority state and federal programs. Such conservation programs would focus on financing irrigation system improvements that represent a substantial investment for farmers. The agricultural community along the RGCP, at present, does not have a clear incentive for investing in water conservation. Economic incentives to compensate for water rights attached to any saved water are likely needed to foster such on-farm water conservation programs (EBID 1998).

Water banking is a water management strategy that speeds up the temporary transfer of water from those willing to lease it to those willing to pay to use it. Farmers and other water rights holders can deposit some or all of their allotted water into a "water bank" where users pay the going market rate to borrow it for a limited period of time. The lessor retains ownership of the water rights, and rights placed in the bank cannot be forfeited for non-use (Salem 2002).

The water banking concept is gaining support in the State of New Mexico. In November 2002, the State Engineer's Office issued draft regulations for water banking in the Lower Pecos River Basin (NMOSE 2002). While this is a very restricted program for a specific basin, in the future it could lead to a broader application of such programs in the state.

Salt Cedar Removal

Extensive salt cedar growth, an invasive species with high water consumption, is found along the RGCP. Estimates of annual water use, summarized by Weeks *et al*. (1987) range from 3.3 to 11 ft/yr, nearly twice the typical water use reported for native cottonwoods. Given the elevated water consumption, salt cedar removal was considered in the AFR to reduce water consumption in the floodway, and for subsequent transfer of the saved water for riparian vegetation development and other environmental measures.

In the reformulation of alternatives, salt cedar removal was no longer considered a viable approach to secure water due to its high cost, difficulty to reliably quantify actual water use reduction, and uncertainty in obtaining NMOSE authorization for trading saved water for surface water use.

Recurrent Flood Cycles

Riparian vegetation can be developed along low-elevation areas by shaving of stream banks to increase the possibility of recurrent flooding. The method is based on small-scale flood cycles likely to occur at 1 to 3-year intervals. The method relies on natural overbank flow conditions during storm events. There are two consideration in the use of this method. First, there is no certainty that soil preparation activities would always coincide with adequate overbank flow conditions. Second, any water arriving into the RGCP either through the reservoirs or as runoff downstream of the dams constitutes Rio Grande Project water, thus requiring agreements with EPID and EPCIWD#1 prior to use. Application of this measure was discussed in Subsection 3.3 as part of the Integrated USIBWC Land Management Alternative.

Groundwater Use

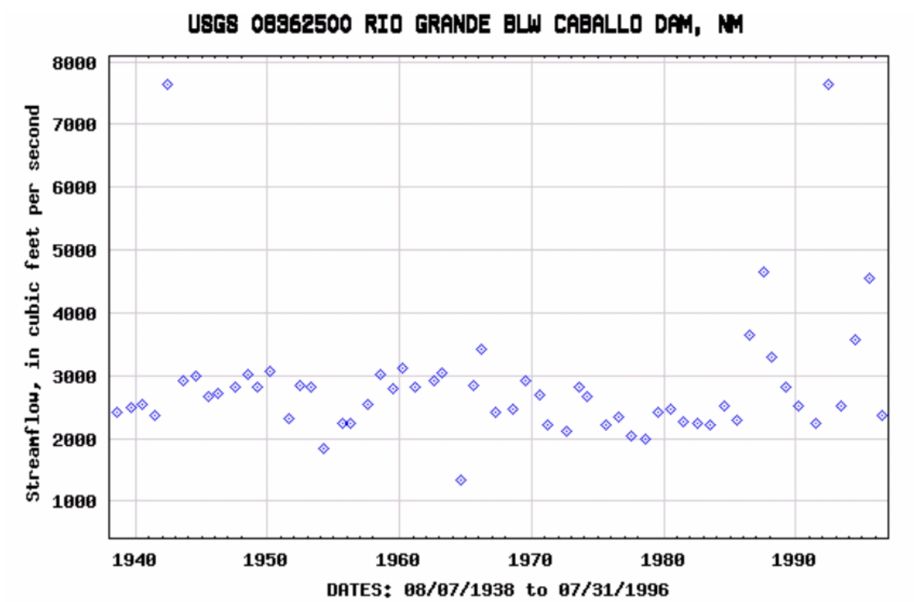
Groundwater is used by farmers in the Rincon and Mesilla Valleys to supplement reduced surface water allocations during severe droughts. In New Mexico, this use must comply with the State's comprehensive groundwater regulatory system based on the doctrine of prior appropriation. In Texas, groundwater use requirements are more flexible as they are based on the right-of-capture rule (EPCWID#1 2000).

Groundwater could be used for establishment of riparian vegetation along the RGCP. Experimental plots supported by groundwater use, tested by the U.S. Department of Agriculture, Natural Resources Center, have proven successful in promoting regeneration of Rio Grande cottonwood seedlings using micro-irrigation systems (Dressen *et al*. 1999).

4.1.5 Water Delivery Limitations

Given an adequate water supply, the existing water delivery system also places limits on the potential transfer of water for environmental measures. For example, the operational regime of Caballo Dam and capacity of the discharge structures determine the maximum rates and duration of controlled water releases to induce overbank flows. At full reservoir capacity, Caballo Dam discharges into the RGCP through discharge structures are physically limited to 5,000 cfs. Historically, peak daily discharges have been within the 2,000 to 3,000 cfs range (Figure 4-3).

Figure 4-3 Daily Peak Discharges from Caballo Dam



RGCP Main Channel

The RGCP main channel was designed with a hydraulic capacity that ranges from 2,500 to 3,000 cfs in the Upper Rincon Valley, to less than 2,000 cfs in the Lower Mesilla and El Paso Valleys (Parsons 2001a).

Figure 4-4 is a schematic of the Rio Grande showing diversion and drain return points in the RGCP, and operational average flows during irrigation seasons, non-irrigation seasons, and for both seasons combined. Throughout the RGCP, drain flows that return to the river above American Diversion Dam are reused to supply demands lower in the system. The typical average flow ranges from 600 cfs to 1,100 cfs during the March to October irrigation season, and decreases to less than 200 cfs from November to February (Figure 4-4).

Figure 4-4 Typical Flow Distribution Along the RGCP

Inflow / Outflow	Location	Average Flow (cfs) Mar-Oct	Nov-Feb	Annual
	Release from Caballo Dam[b]	**1,301**	**167**	**923**
	Percha Dam			
Percha Lateral/Arrey Canals (350 cfs)[a]	*Water Diversion*	*(160)*	*(20)*	*(114)*
	Downstream Release[c]	**1,141**	**147**	**809**
Garfield, Hatch, Angostura and Rincon Drains	*Return Flows*[d]	78	16	58
	Seldon Canyon[b]	**1,219**	**163**	**867**
	Leasburg Dam			
Leasburg Canal (625 cfs)[a]	*Water Diversion*[b]	*(265)*	*(13)*	*(181)*
	Downstream Release[c]	**954**	**150**	**686**
Seldon & Picacho Drains	*Return Flows*[e]	80	4	54
	Mesilla Dam			
East and West Canals (950 cfs)[a]	*Water Diversion*[b]	*(455)*	*(27)*	*(312)*
	Downstream Release[c]	**579**	**127**	**428**
Del Rio, La Mesa, Anthony, East, Montoya Drains, other	*Return Flows*[d]	196	97	163
	Upstream of American. Dam[b]	**774**	**224**	**591**
American Canal (1,200 cfs)[a]	*Water Diversion*[b]	*(595)*	*0*	*(397)*
	Downstream Release[c]	**179**	**224**	**194**
Acequia Madre	*Diversion at International Dam*[b]	*(102)*	*0*	*(68)*

a. Maximum diversion capacities, in parenthesis, from U.S. Bureau of Reclamation (www.usbr.gov)

b. Values in boldface indicate stream flows. Values as reported in the Draft EIS, El Paso-Las Cruces Regional Sustainable Water Project (USIBWC & EPWU/PSB, 2000: Table 3.3-17).

c. Releases from dams were calculated as the difference between upstream flow and diverted flow.

d. Return flows were calculated as the difference between upstream and downstream flows.

e. Mesilla Valley return flows represent 30% of the diverted flow (USIBWC & EPWU/PSB, 2000, p. 3-10)

Caballo Dam discharges are initially diverted upstream of the RGCP, at Percha Dam. Water flow is subsequently rerouted for irrigation at three diversion dams that pre-date the RGCP: Leasburg Dam, Mesilla Dam, and American Diversion Dam. Most of the flow past American Diversion Dam is diverted south of the RGCP, at the International Dam, to meet U.S.-Mexico Treaty agreements.

Diversion dams contain gate structures to route irrigation water from the RGCP to adjacent canals. Excess water overtops the dams and continues downstream. The canals leading from the diversion dams provide irrigation water to surrounding agricultural land through a network of canals and laterals.

Irrigation Distribution System

Water is removed from the agricultural land by a series of drainage canals and spillways that eventually flow back into the RGCP. The drains and spillways enter the ROW by passing through the flood protection levees. Some drains are equipped with gate valves or control structures at the levee crossing which regulates water level in the drains. The gate valves and control structures are designed to be closed during a flood to prevent water from backing into the canal system and flooding land outside the levees.

In addition to the diversion dams and canals, there are five water-conveyance structures that cross the RGCP channel and ROW. Three siphons, the Rincon, Hatch, and Garfield siphons, convey water from canals on one side of the river to the other. A fourth siphon, the Montoya siphon, carries drainage water and runoff under the river to the drainage canal flowing through southern El Paso. The siphons were constructed to pass below the bed of the river. The fifth structure, the Picacho flume, consists of two elevated 42-inch diameter pipes supported by concrete piers on top of timber piles that cross the floodway and channel to convey irrigation water from east to west.

Two of the siphons, Hatch and Rincon, are protected from erosion by boulder dams across the RGCP channel. New erosion protection structures have been designed for both siphons, and for the Picacho Flume (Montgomery Watson 2000 and 2001, respectively). Siphon erosion protection structures provide a diversified aquatic habitat with backwater areas of low velocity water behind the dams, and white-water habitat created by water flowing over and down the structures for energy dissipation.

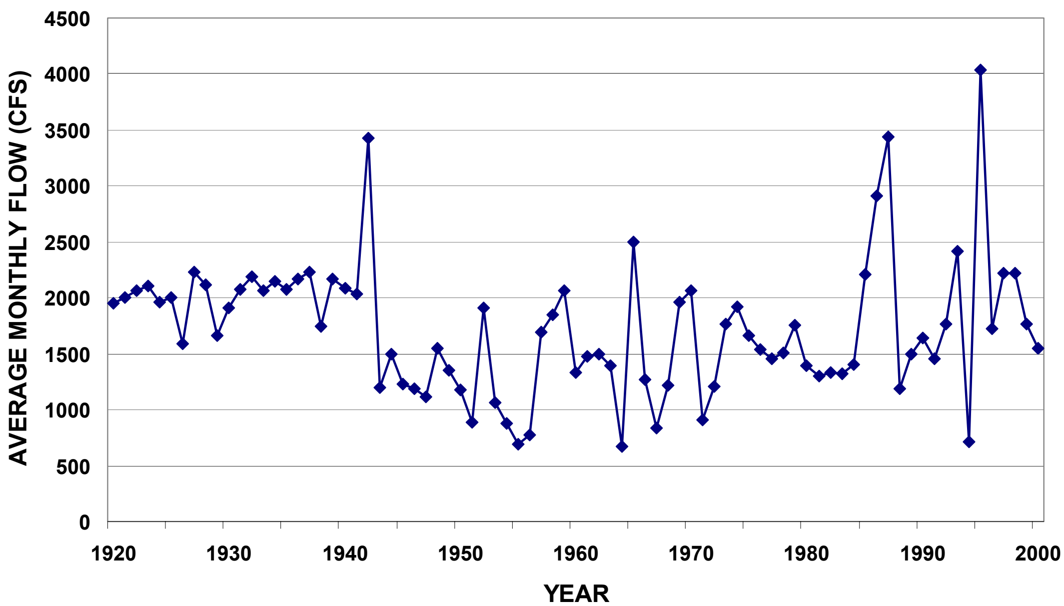
4.2 RIVER CONFIGURATION AND SEDIMENT TRANSPORT

Over the past century flow regime control and physical modifications to the streambed have drastically changed the configuration of the Rio Grande along the RGCP. Nearly all major changes pre-date the RGCP by decades. Understanding the extent of upstream flow control, historical changes in stream configuration, and sediment transport give a realistic view of the ecosystem restoration potential along the RGCP. Those three factors are discussed below.

4.2.1 Flow Regime

Flow regime (magnitude, frequency, duration, timing, and rate of change of hydraulic conditions) within the RGCP was a primary consideration for virtually all environmental measures. Regulation of the stream flow has had little change since early 1900's. Figure 4-5 shows average discharges downstream of Elephant Butte Reservoir during summer conditions (*www.usbr.gov*). Average values remained near 2,000 cfs until 1940, fluctuated from 500 cfs to 2,000 cfs during low-precipitation conditions prevalent for the following four decades, and experienced greater fluctuations during high-precipitation periods of the mid 1980s and 1990s.

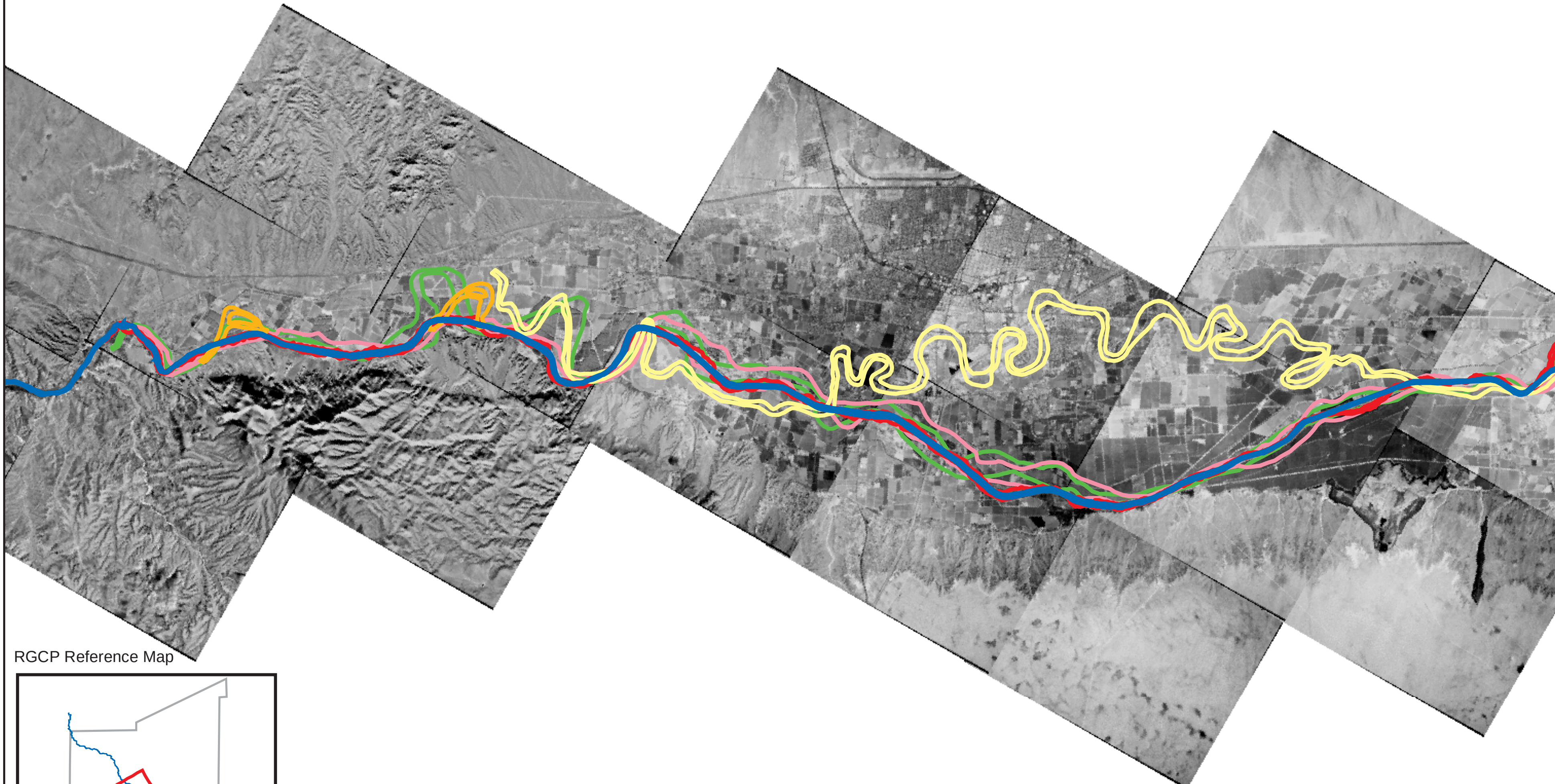
Figure 4-5 Historical Discharges from Elephant Butte for the Month of July



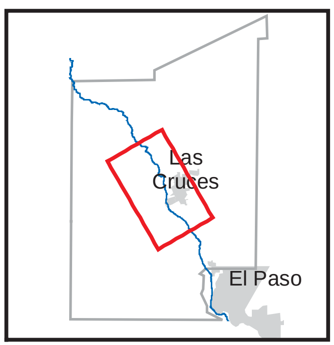
4.2.2 Physical Changes

Pre-Canalization

Pre-canalization conditions were characterized by wide changes in stream configuration and streambed width. Changes in the Mesilla Valley since 1844 and since 1903 in the upper El Paso Valley are illustrated in Figures 4-6 and 4-7, respectively (data provided in April 2003 by the New Mexico Resource Geographic Information System, *http://rgis.unm.edu/intro.cfm*). Major reductions in stream length were made before 1907 by river straightening to facilitate water delivery and improve flood control. The greatest changes to river sinuosity occurred in the El Paso area, including a flood control project known as the Vinton cutoff (Figure 4-7). Major changes also occurred prior to 1938 due to flow regulation by a series of upstream reservoirs that include Elephant Butte.



RGCP Reference Map



NORTH -60

SCALE = 1 : 180,000 or 1 INCH = 3 MILES

0 2.5 5 Kilometers

0 2.5 5 Miles

LEGEND

- Current Channel
- 1938 Streambed
- 1912 Streambed
- 1907 Streambed
- 1903 Streambed
- 1844 Streambed

Overlays: 1996 Aerial Photograph
(DOQ, Band 1, grayscale)

Figure 4-6

Comparison of Current Channel and Historical Streambeds in the Upper Mesilla Valley

PARSONS

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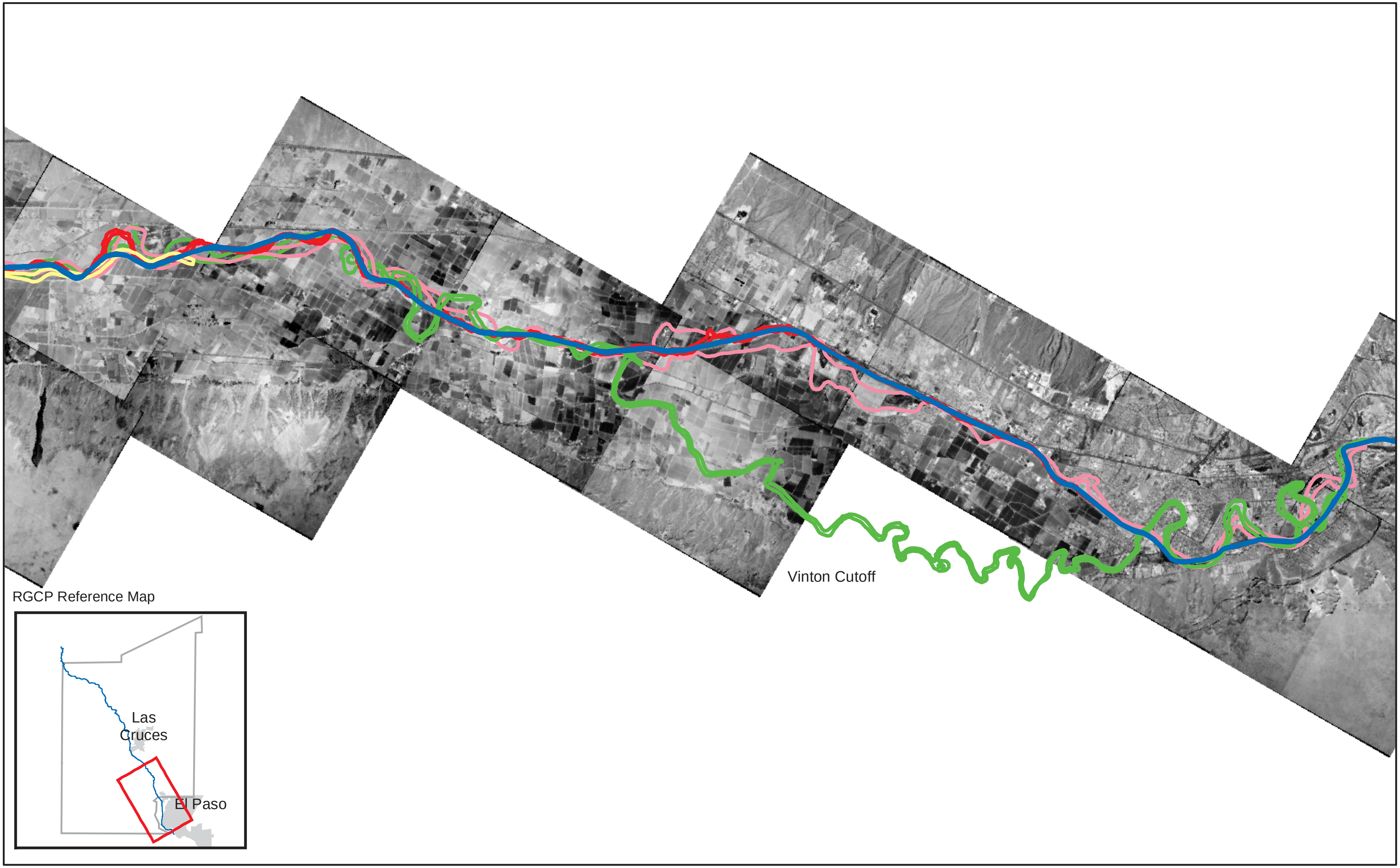


NORTH -60

SCALE = 1 : 180,000 or 1 INCH = 3 MILES

0 2.5 Kilometers

0 2.5 5 Miles

LEGEND

- Current Channel
- 1938 Streambed
- 1912 Streambed
- 1907 Streambed
- 1903 Streambed
- 1844 Streambed

Overlays: 1996 Aerial Photograph
(DOQ, Band 1, grayscale)

Figure 4-7

Comparison of Current Channel
and Historical Streambeds
in the Upper El Paso Valley

PARSONS

Canalization

Canalization of the Rio Grande was accomplished from 1938 to 1943 by creating a deeper pilot channel for conveyance of irrigation flows and water deliveries. The modified channel largely followed the existing streambed configuration (Appendix A). As part of the construction, some islands and braided channels were modified or eliminated, and a number of meanders were straightened. The majority of these meanders were less than half a mile. According to the RGCP construction report, overall reduction in river length along the RGCP was about 5 percent, to 105.4 miles (Baker 1943). The average river bed slope increased from 0.073 percent to 0.074 percent as a result of the straightening. Canalization also included hardening of channel banks to prevent reformation of meanders and bends.

Current

The RGCP has largely retained its original configuration since its completion in 1943. Stream banks were routinely stabilized, primarily by riprap placement, until the mid-1970s when construction of NRCS flood control dams in tributary streams, in combination with upstream flow control, provided greater stability to the channel. In a technical evaluation of the RGCP functionality (USACE 1996), bank stabilization was recommended for approximately 18,000 linear feet. Bank stabilization with sand bar willow was recommended as a multi-objective technique for bank protection, sediment input reduction, and improved riparian habitat (USACE 1996). Planting was recommended either individually or in combination with riprap or soft technologies such as grass seeding, brush planting, or grid fabrics.

4.2.3 Sediment Control

Tributary Basin

The total watershed area draining to the RGCP below Percha Dam is 823 square miles at Leasburg Dam, 875 square miles at Mesilla Dam, and 921.6 square miles at American Diversion Dam (USACE 1996). The upper watershed was characterized by USACE (1996) as a high-bed load sediment system associated with multiple steep arroyos (Type D4 in the Rosgen classification). In addition to contributing to channel flow, arroyos deposit sand, gravel, and boulders, providing a major constituent of the Rio Grande sediment budget. Between 1969 and 1975, the NRCS, at the request of the USIBWC, constructed sediment control dams at Broad Canyon, Crow Canyon, Green Arroyo, and Jaralosa Arroyo to decrease the sediment load into the river. In combination, these four tributaries drain over 300 square miles of the upper RGCP watershed. Additional sediment control dams and flood control dams have been built on smaller arroyos draining into the RGCP.

The 1996 USACE study also evaluated the sedimentation rate from tributary basins to the RGCP. Table 4-1 lists major arroyos, size of the drainage area, location of their confluence with the Rio Grande, and the presence of sediment control dams. The table gives the average annual computed total sediment load for major arroyos sorted by volume. The most significant sediment loads (greater than 10 acre-feet per year) are generated in the Rincon Valley, and are largely associated with tributary basins without control dams (Rincon, Bignell, Placitas, and Montoya Arroyos; Tierra Blanca Creek; and Trujillo and Faulkner Canyons).

Table 4-1 Significant Sediment Loads Reaching the RGCP (USACE 1996)

Name	Drainage Area (sq. miles)	Existing Dam?	Confluence (miles above American Dam)	Average Annual Total Sediment Load (acre-feet)
Rincon Arroyo	124.7	No	78.9	33.52
Tierra Blanca Creek	68.2	No	100.4	22.09
Trujillo Canyon	52.9	No	103.1	18.88
Bignell Arroyo	8.9	No	76.2	16.88
Placitas Arroyo	34.6	No	85.7	14.91
Sibley Arroyo	27.2	No	98.9	13.22
Faulkner Canyon	25	No	63.8	12.70
Montoya Arroyo	23	No	101.8	12.22
Foster Canyon	11	No	64.5	9.06
Reed Arroyo	9.6	No	78.5	8.64
Yeso Arroyo	9.5	No	94.9	8.60
Angostura Arroyo	8.9	No	80.2	8.41
Buckle Bar Canyon	2.12	No	67.6	5.41
Arroyo Cuervo	126.2	Yes	93.5	3.38
Berrenda Creek	87.4	Yes	97.4	2.60
Broad Canyon	68	Yes	67.6	2.20
Green Canyon	35.6	Yes	100.4	1.51
Nordstrom Arroyo	16.7	Yes	103.1	1.06
McLeod Arroyo	14.2	Yes	93.9	1.00
Box Canyon	8.7	Yes	49.8	0.83
Apache Canyon	7.8	Yes	49.8	0.80
Spring Canyon	7.4	Yes	80.2	0.79
Jaralosa Arroyo	6.8	Yes	95.2	0.77
Doña Ana Arroyo	6.9	Yes	51.2	0.77
Reed-Thurman Dam Drain	3.3	Yes	83.0	0.61
Ralph Arroyo	2.5	Yes	80.2	0.56

Main Channel

The main channel of the RGCP is maintained to remove debris and deposits, including sand bars, weeds, and brush growing along the bed and banks. Any major depositions or channel closures caused by sediment loads from arroyo flows are removed. The USIBWC also maintains the grade of the channel bed at the mouth of the arroyos to ensure the channel conveys irrigation deliveries. Sediment collected from channel excavation, arroyo mouth maintenance, and other sediment control efforts is deposited on the floodway, on upland spoil areas, or on other federal or private lands approved for this purpose.

The USIBWC conducted sediment removal from arroyos in 1998, and completed mitigation measures as required by the USACE Section 404 dredging permit. Thirteen artificial aquatic habitat structures were constructed, and monitored over a 3-year period.

Because the 1970 dams in tributary basins control over one-third of the upper RGCP basin north of Leasburg Dam (USACE 1996), dredging of the main channel has been conducted infrequently. A study on the scour and deposition of sediments within the main RGCP channel was conducted by the USACE (1996) as part of an evaluation of the RGCP functionality. The extent of bed elevation changes in the channel was evaluated for low, high, and 100-year flows.

The USACE study concluded that low flow conditions over the course of a year would result in only minor scour and deposition along the river. For the 100-year flood, changes ranged from a maximum deposit of 0.7 feet to maximum scour of 1.7 feet. Significant deposition (greater than 5 feet of sediment) was predicted for channel cross sections downstream from Rincon Arroyo, Trujillo Canyon, Tierra Blanca Canyon, Placitas Arroyo, and Faulkner Arroyo. More significant maximum scour (2.6 feet) and maximum deposition (1 foot) were estimated for a 10-year period of consecutive high flows (USACE 1996).

4.3 FLOOD CONTROL EVALUATION

The configuration of natural streams is largely dictated by the extent and frequency of flooding events. In most North American streams, however, flows have been heavily regulated by upstream reservoir operation. This is the case of the RGCP where multiple reservoirs were constructed over the last century for flood control and irrigation water storage control flow regimes. As part of the river management alternatives formulation, flood control in the RGCP was evaluated in the context of river restoration potential. In particular, potential opportunities for implementation of environmental measures were evaluated considering non-structural flood control measures such as levee relocation to increase the active flood plain size.

4.3.1 Flood Control Strategy

The RGCP flood control system was constructed in conjunction with the canalization from 1938 to 1943. The system was designed to provide protection from a storm of large magnitude with a very low probability of occurrence, the 100-year storm (probability of one event every 100 years). Flood control in the RGCP relies largely on upstream flow regulation, as well as the use of levees, to contain high-magnitude flooding in areas with insufficient natural terrain elevation.

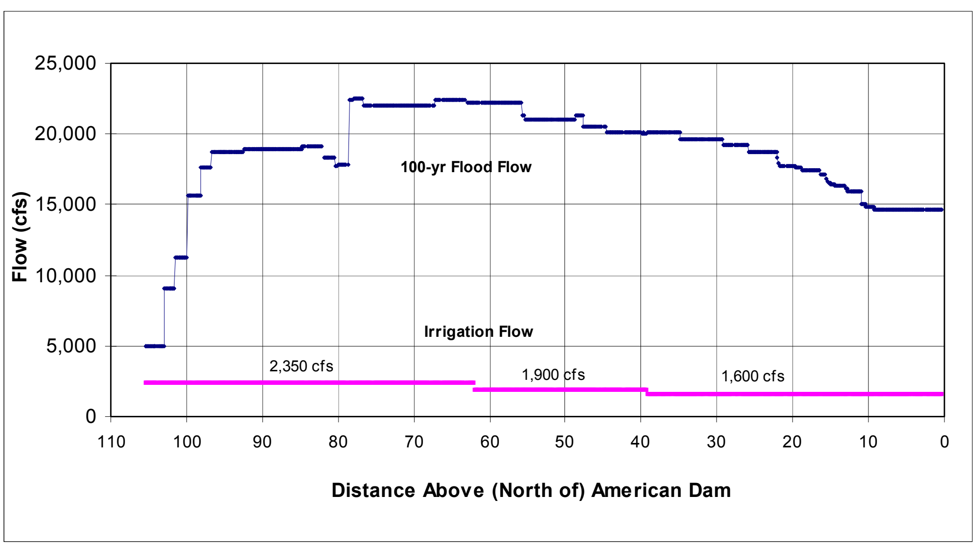
The flood control levees extend for 57 miles along the west side of the RGCP, and 74 miles on the east side for a combined total of 131 miles. Naturally elevated bluffs and canyon walls contain flood flows along portions of the RGCP that do not have levees. The levees range in height from about 3 feet to about 18 feet and have slopes of about 3:1 (length to width) on the river side and 2.5:1 on the "land" side. The levees have a crown width of 20 feet with a gravel maintenance road along the top.

The levees are positioned on average about 750 to 800 feet apart north of Mesilla Dam and 600 feet apart south of Mesilla Dam. The floodway between the levees is generally level or uniformly sloped toward the channel. The floodway contains mostly grasses, some shrubs, and widely scattered trees. The bank of the channel at the immediate edge of the floodway is typically vegetated with a narrow strip of brush and trees. Levees were originally built to provide 3 feet of freeboard during the design flood in most reaches.

Other flood control measures were established along several large arroyos at their confluence with the Rio Grande because, prior to canalization, these arroyos flooded large flood plain areas during heavy rainstorms. Earthen dams were constructed within the inner canyons and along the lower drainage levees to channel stream flow, reduce erosion, and prevent further flood damage. USACE (1996) estimated that those dams reduced the 100-year storm magnitude by 40 percent relative to the storm used in the 1936 design of the levee system.

Figure 4-8 illustrates the design flood flow of the RGCP, which ranges from 20,000 cfs at Leasburg Dam to 17,000 cfs at El Paso. The design flow for maximum operation conditions during the irrigation season (channel capacity) is also presented as a reference. Typical operation flows during the main irrigation system, previously presented in Figure 4-4, range from 600 cfs to 1,200 cfs.

Figure 4-8 Magnitude of the 100-Year Flood along the RGCP Relative to Design Flow



4.3.2 Flood Containment Capacity Analysis

A flood control study of the RGCP was completed in 1996 by the USACE. Hydraulic modeling of the RGCP was performed to determine its capacity to contain the 100-year flood within the ROW using the hydraulic model HEC-2. This model estimates the height of the peak flood as it progresses from the upstream reaches of the river. Because evaluation of the 100-year flood levels is a risk management tool for extremely large floods of rare occurrence, analysis is based on conservative assumptions. There is also a potential for over-estimating actual risk because the hydraulic model used in flood simulations (HEC-2) accounts for longitudinal attenuation of the flood peak along the RGCP (one-dimensional simulation), but does not incorporate the attenuation effect of horizontal dissipation over the floodway (two-dimensional simulation).

A number of potential deficiencies in the RGCP were reported by USACE (1996) based on modeling of a 100-year storm event, and levee system's capability to contain the simulated water levels. For some sections of the RGCP, levee rehabilitation or placement of new levee segments or floodwalls was recommended. A freeboard with a minimum 3-foot height was used as the flood containment design criteria. Because the levee system was constructed nearly 60 years ago, there is also the possibility of structural deficiencies in some levee sections, an issue currently under evaluation by the USIBWC (Section 3.6.1).

Hydraulic modeling results, coupled with findings of the ongoing structural condition evaluation of the levees, will serve as the basis for USIBWC to re-evaluate future long-term flood control strategy for the RGCP. In addition to the physical rehabilitation of the levees, the future flood control strategy could incorporate non-structural flood control measures such as levee relocation, removal of sediment located within the flood plain that was deposited from dredging operations since project inception, and financial agreements with landowners for the use of flood control easements.

4.3.3 Potential Role of Non-Structural Flood Control in the RGCP Stream Restoration

Coupling of non-structural flood control measures with riparian ecosystem restoration has been successful in riverine systems with large recurrent flood events, such as the Missouri River (Rasmussen 1999a) and Ohio River (Parsons 2000b). In these systems, many reaches designed for high magnitude floods had actually been subject to frequent flooding. For example, the Interagency Flood Plain Management Review Committee, following analysis of the devastating flooding in the Midwest in 1993, reported that many districts had actually been flooded five to 10 times during the previous 50 years (Cunniff 1997). A significant factor in the flooding was the extensive and unregulated placement of levees by agencies and landowners (Rasmussen 1999b). Under these conditions, levee relocation and use of other non-structural flood control measures offer numerous opportunities to combine flood control and river restoration measures.

Flood conditions in the Midwest differ radically from those in the RGCP where the levee system was built as a single, planned project, and its operation for over 60 years has been conducted entirely by a single agency, the USIWBC. In the RGCP, where low precipitation is prevalent and flooding is tightly controlled by upstream reservoirs, flood control needs and stream restoration opportunities differ substantially from those applicable to the Missouri and Ohio Rivers. In addition to Elephant Butte Dam, completed in 1916, flood regulation upstream of the RGCP was increased by four reservoirs constructed under the Flood Control Act of 1941: Jemez Canyon Dam (1953), Abiquiu Dam (1963), Galisteo Dam (1970), and Cochiti Dam (1975). These dams have effectively controlled floods originating in the upper Rio Grande Basin (Winter *et al*. unpublished manuscript). Additional flood control is expected as a result of the Upper Rio Grande Water Operations Model (URGWOM), a multi-agency initiative to optimize water storage and delivery operations throughout the Rio Grande from Colorado to Texas (*www.spa.usace.army.mil/urgwom*). Improved flood routing through the RGCP is a component of the simulation model

Given the tightly regulated upstream flow, few significant flood events, all contained within the levee system, have been registered in 60+ years of RGCP operation. Unlike non-structural flood control programs implemented for rivers with recurrent high flood events where non-structural methods provide both flood protection and environmental improvement opportunities, the use of non-structural flood control methods in the RGCP is primarily an economic and risk-management decision. Table 4-2 illustrates the reduction in peak floods at El Paso, Texas, following completion of Elephant Butte Dam in 1916 and Caballo Dam in 1938 (USACE 1996).

Table 4-2 Floods of Record at El Paso, Texas

Year	Date	Peak Discharge (cfs)
Prior to Elephant Butte Construction		
1897	May 27	18,200
1903	June 21	18,100
1904	October 15	17,100
1905	June 12	24,000
Prior to Caballo Dam Construction		
1925	September 3	13,500
1933	August 5	5,010
1935	August 31	7,120
After Caballo Dam Construction		
1950	July 14	7,740
1957	July 26	4,730
1958	September 14	11,600

As discussed in Subsections 4.1 and 4.2, the active RGCP flood plain is largely controlled by high irrigation flows and low-magnitude floods regulated by upstream reservoirs, not by the large and rare 100-year flood events the levees are intended to control. The existing levee system does not dictate the active flood plain in the RGCP, or current river configuration.

Under these conditions non-structural measures such as levee relocation remain an option for flood control in some segments of the RGCP, but are not a significant element in the consideration of restoration opportunities.

4.3.4 Potential for Levee Relocation as a Non-Structural Flood Control Measure

The potential use of non-structural flood control measures was evaluated on a conceptual basis for the RGCP. This evaluation was not intended to be a flood control study, but an assessment of additional opportunities for ecosystem restoration. Reevaluation of flood control strategies is an ongoing task conducted by the USIBWC as part of its mission, and whose scope is beyond the evaluation of river management alternatives for the RGCP.

Levee relocation was evaluated as a potential non-structural flood control measure for the RGCP. The evaluation was performed by identifying reaches of the levee system with potential flood containment deficiencies, in conjunction with adjacent land use categories. The conceptual evaluation was based on the following criteria:

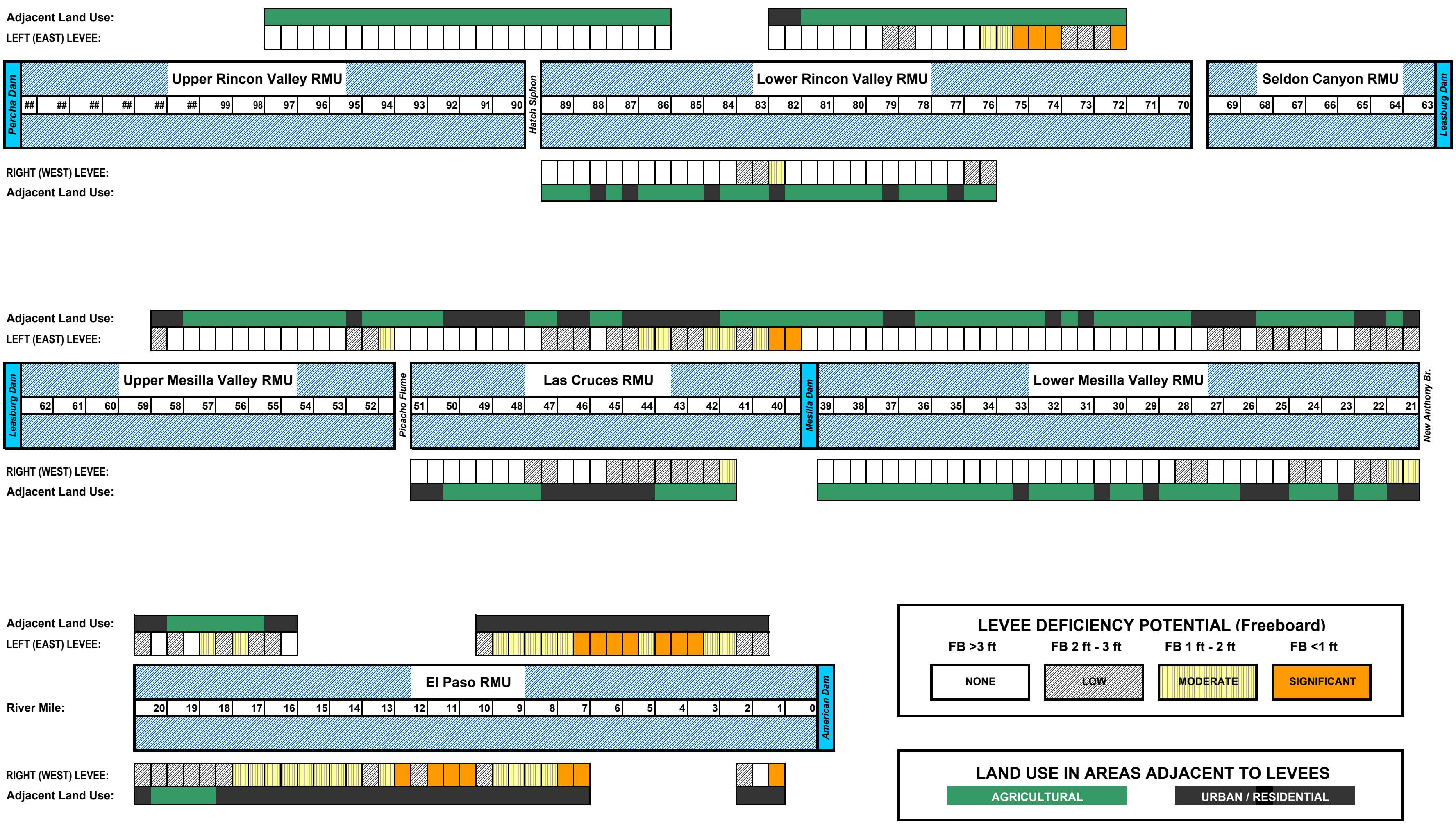
- Levee relocation would be justified only at locations where a significant potential for flood containment deficiencies is identified (inadequate freeboard).
- Levee deficiencies adjacent to urbanized areas must be addressed by levee rehabilitation at their current location (structural measures).
- Deficient levees adjacent to large rural areas would offer a potential for establishing flood easements and/or partial modification of the levee system.

Results of the USACE hydraulic modeling of the RGCP, and modifications to the original model as part of the EIS evaluation, were discussed in the AFR (Parsons 2001a). Table 4-3 presents tabulated results for each of the seven geographic reaches of the project (RMUs). Figure 4-9 summarizes potential levee deficiencies identified in terms of freeboard.

Table 4-3 Potential Deficiencies for Flood Containment

	Entire Project	Upper Rincon	Lower Rincon	Seldon Canyon	Upper Mesilla	Las Cruces	Lower Mesilla	El Paso
River Mile	*105 - 0*	*105 - 90*	*90 - 72*	*72 - 63*	*63 - 51*	*51 - 40*	*40 - 21*	*21 - 0*
Current Flood Control (miles)								
Unconfined ROW length	81	24	9	18	13	3	1	13
Existing Levees	131	8	27	0	8	23	38	27
Potential Deficiencies (miles)								
Flood Limit Beyond ROW	12	0	1	3	1	0	0	7
Insufficient Freeboard								
Freeboard less than 1 ft.	13	0	2	0	0	2	0	9
Freeboard from 1 ft. to 3 ft.	51	0	5	0	3	13	10	20

Figure 4-9 RGCP Characterization by River Management Unit in Terms of Potential Levee Deficiencies and Adjacent Land Use



Hydraulic model simulations, based on estimated peak water elevations for the 100-year flood, identified 13 miles of levees with potentially significant deficiencies in terms of height. Potential deficiencies were also identified for 12 miles of unconfined RGCP sections where simulated flood levels could extend past the ROW. Most of the potential deficiencies identified are located largely in the southern, mostly urbanized reaches of the RGCP (El Paso RMU).

Modeling results also indicated that up to 51 additional miles of levees could require an increase in height, up to 2 feet, to meet the freeboard design criterion for protection against a 100-year flood (Table 4-3). Moderate levee height deficiencies were excluded from the non-structural flood control analysis because simulated water elevation estimates are based on very conservative assumptions, and no structural deficiencies have been identified. In addition, most potentially deficient sections are adjacent to residential areas.

Overall, the combined evaluation of potential levee deficiencies and adjacent land use in the RGCP shows a very limited potential for levee relocation as a non-structural flood control measure and its use in support of river restoration. Under conditions simulated by the hydraulic model, an analysis of levee relocation would be warranted in only two RGCP reaches where significant levee deficiencies are adjacent to agricultural lands (Figure 4-9):

- The downstream end of the Rincon Valley, from river miles 72 to 76, where model results indicate that the east (left) levee elevation might be inadequate for control of the 100-year flood; and
- The downstream end of the Upper Mesilla Valley, north of Mesilla Dam, from river miles 40 to 41 (left levee).

4.4 RIVER RESTORATION ANALYSIS

4.4.1 Conceptual Basis for the RGCP Restoration

While there is a broad interest in developing restoration approaches for the Middle Rio Grande bosques, there is no consensus as to how to achieve this goal beyond fairly broad concepts such as "mimicking typical natural hydrographs" and "allowing fluvial processes to occur within the river channel and the adjacent bosque." Recent reviews of ongoing restoration efforts point out that returning the Rio Grande to some designated historical state is not a realistic option, given that the system has undergone too many substantial and irreversible changes (Molles *et al*. 1998; Crawford *et al*. 1999). As a result, natural processes (flood events, scouring and sedimentation processes) would be replaced by man-made events (mechanically moving soil, opening meanders and managed flows) thereby restoring physical characteristics on a smaller scale.

The view that historical widths, sediment loads, and peak flows are not needed to return to a functioning system was a conclusion also reached by the Bosque Hydrology Group (BHG) in their analysis of Middle Rio Grande rehabilitation (BHG 2001). The technical group comprised of representatives of various federal agencies, universities and conservancy districts —created to implement the Bosque Biological Management Plan and synthesize findings of ongoing bio-hydrologic studies— concluded that functioning of the system can be optimized by working within a scaled down river framework. This rehabilitation concept has been applied by the BHG to various reaches of the Middle Rio Grande (2001).

Two basic goals, described below, were adopted by the USIBWC as the conceptual basis for RGCP restoration: development of a riparian corridor based on the partial restoration concept, and diversification of aquatic habitats.

Riparian Corridor Development Based on the Partial Restoration Concept

Because of the substantial changes that have occurred to the Rio Grande, several leading researchers advocate the flexible concept of "partial restoration" (Molles *et al.* 1998, Crawford *et al.* 1999) as it pertains to the Rio Grande bosque. Partial restoration is defined as "seasonal soil wetting at carefully selected riparian locations in order to bring about establishment and/or maintenance of native woody vegetation" (Crawford *et al*. 1996). This practice also promotes decomposition, mineralization, and nutrient recycling (Ellis *et al*. 1999). Based on several years of experience in the Middle Rio Grande, mostly in the Bosque del Apache National Wildlife Refuge, Crawford *et al.* (1999) concluded that partial restoration can be achieved through a combination of various methods, such as simulated flooding, manipulation of flow regime, and alteration of bank structure. The concept has been successfully implemented in the Middle Rio Grande at the Albuquerque Restoration Project (Crawford *et al.* 1999).

Development of a native riparian corridor is potentially attainable through modification of RGCP management practices (mowing and grazing) and mechanical manipulation (moving soil, opening meanders, and managing flows). Key to sustainability is the selection of restoration sites where natural regeneration and maintenance are possible (hydrologic flood plain). Partial restoration provides a realistic and tested approach for riparian corridor development within the RGCP.

Premises for selection of environmental measures for riparian corridor development, discussed in Subsection 4.4.4 are:

- Flow regime regulation by a reservoir network that includes Elephant Butte largely dictates current stream geometry and the active hydrologic flood plain.
- Upstream reservoir operation, as well as major changes in stream geometry by loss of large meanders, pre-date RGCP construction. Consequently, river conditions in 1938 were adopted as a reference for potential restoration as part of the river management alternatives for the RGCP.
- The RGCP channel is relatively stable due to upstream flow control, and construction of sediment control dams in tributaries in the 1970s. Since then, there has been little need for riprap placement along the stream banks.
- The levee system was placed outside the active flood plain given its function to control the 100-year flood. Restoration potential in the RGCP is not associated with that rare and destructive flood event, but with much smaller flood events of greater recurrence.

- Mowing in the floodway controls salt cedar invasion, and must be continued unless replaced by native riparian bosque or managed grasslands.
- Riparian corridor development requires water acquisition, a very limited and fully allocated resource.
- A restoration program requires cooperation with irrigation districts, compensation for water use, and incorporation of water conservation measures as a key element.
- Controlled water releases from Caballo Dam could support development of established riparian vegetation in the Rincon Valley.

Aquatic Habitat Diversification

Manipulating aquatic habitat through artificial structures, simulated flooding, and modification of flow regimes is being applied in various sections of the middle Rio Grande. Just as extensive bosque restoration throughout the RGCP is not a realistic option, large scale restoration of the aquatic system is not feasible either; rather, emphasis should be placed on diversification of aquatic habitat. Diversification is potentially attainable on a limited scale through modification of USIBWC management practices such as dredging and grazing in floodway, artificial measures such as embayments, and limited modification of channel geometry (*i.e.* reopening of meanders).

Aquatic habitat diversification was addressed by reopening low-elevation meanders cut off during RGCP construction and the creation of embayments in arroyos. The excavation of the Rio Grande during RGCP construction created a relatively homogeneous aquatic habitat characterized by deep, fast-moving waters during the irrigation season. A USIBWC-sponsored study of aquatic habitat availability indicated that fast-moving water conditions prevalent in the RGCP during the irrigation season do not coincide with reproduction preferences of native fish species (CH2M-Hill and GeoMarine 2000). Figure 4-10 presents a comparison of needed habitat conditions for fish reproduction, and habitat availability in the RGCP at flows representative of the irrigation and non-irrigation seasons (1,000 cfs and 50 cfs, respectively). Reopening low-elevation meanders and creation of embayments in arroyos would increase aquatic habitat diversity.

Premises for selection of environmental measures for aquatic habitat diversification, discussed in greater detail in Subsection 4.4.4 are:

- The vast majority of the streambed was retained within ROW during the canalization process (Appendix A).
- Canalization created a relatively homogeneous habitat, with fast-moving waters unsuitable for reproduction of most native fish species.
- Key needs for aquatic ecosystem improvement are habitat diversification and re-establishment of slow-moving waters for fish reproduction during the irrigation season.

Figure 4-10. Comparison Between Fish Habitat Preference and RGCP Habitat Availability at Two Reference Flows (modified, from CH2M-Hill & GeoMarine, 1999)

HABITAT PREFERENCE BY LIFESTAGE [a]

Lifestage: Sub-Yearling		VELOCITY (feet per second)			
		Quiet [c] (0 - 0.25)	Slow (0.26 - 0.75)	Moderate (0.76 - 1.5)	Fast (>1.51)
DEPTH (feet)	Shallow (0.0 - 1.0)	**21%**	**13%**	6%	0%
	Moderate (1.1 - 3.0)	**21%**	**13%**	7%	0%
	Deep (> 3.0)	**11%**	6%	1%	0%

Lifestage: Yearling +		VELOCITY (feet per second)			
		Quiet (0 - 0.25)	Slow (0.26 - 0.75)	Moderate (0.76 - 1.5)	Fast (>1.51)
DEPTH (feet)	Shallow (0.0 - 1.0)	6%	3%	4%	3%
	Moderate (1.1 - 3.0)	**13%**	**11%**	**10%**	6%
	Deep (> 3.0)	**14%**	**15%**	**10%**	5%

HABITAT AVAILABILITY BY FLOW [b]

Flow: 50 cfs		VELOCITY (feet per second)			
		Quiet (0 - 0.25)	Slow (0.26 - 0.75)	Moderate (0.76 - 1.5)	Fast (>1.51)
DEPTH (feet)	Shallow (0.0 - 1.0)	**16%**	**42%**	**19%**	3%
	Moderate (1.1 - 3.0)	0%	**12%**	6%	0%
	Deep (> 3.0)	0%	0%	0%	0%

Flow: 1,000 cfs		VELOCITY (feet per second)			
		Quiet (0 - 0.25)	Slow (0.26 - 0.75)	Moderate (0.76 - 1.5)	Fast [d] (>1.51)
DEPTH (feet)	Shallow (0.0 - 1.0)	0%	1%	8%	3%
	Moderate (1.1 - 3.0)	0%	0%	5%	**79%**
	Deep (> 3.0)	0%	0%	0%	4%

NOTES

a. Habitat preference is defined as the percentage of species/lifestages that prefer a given hydraulic category
b. Habitat availability is defined by the amount of a given hydraulic category as a percent of the total habitat available.
c. Habitat preference for spawning is largely restricted (nearly 60%) to quiet water at depths greater than 1 foot.
d. Velocities greater than 3 ft., unsuitable habitat at any depth, account for 18% of the total.

Values equal or greater than 10% for a given velocity-depth combination.

- Both habitat diversification and slow-moving waters can be obtained by reopening meanders cut during the canalization, and arroyo habitat modification.
- Sediment accumulation and the need for dredging have been greatly reduced since the 1970s construction of large control dams in tributary arroyos.

4.4.2 Historical Conditions Summary

Historical Setting

Historically, the Middle Rio Grande was characterized by an extensively sediment-loaded, low-gradient flow river resulting in a braided, sinuous channel meandering through a wide flood plain. Snowmelt, widespread summer rains, and localized heavy thunderstorms caused floods and a highly variable river channel (Scurlock 1998). Bosques along the river were dynamic, spreading when weather was favorable, and dying off during periods of prolonged drought or prolonged floods. The river course frequently changed, meandering throughout the valley (Stotz 2000). Figures 4-6 and 4-7 above illustrate the historic river course in the Mesilla and El Paso Valleys.

Prior to RGCP, the construction of storage and regulation reservoirs ended the seasonal floods driving the dynamic equilibrium of the river. Impacts included changes in riparian communities, sediment deposition, changes in flow patterns, reduced water volume, and reduced seasonal variations. Current irrigation flows in conjunction with flood flow attenuation severely altered the complexion of the river as well as the associated course with the current conditions.

Reasons for Decline

Riparian ecosystems in the southwest are declining due to anthropogenic disturbances (Szaro 1989; Briggs 1995, 1996; Crawford *et al*. 1996; Patton 1999). Degradation has been a result of direct impacts as well as the cumulative effect of numerous, indirect impacts (Everitt 1998; DeBano and Schmidt 1989; Schmidly and Ditton 1978). Activities which have negatively impacted riparian systems in the RGCP mirror those throughout the southwest. Causes of decline for the RGCP, either separately or in combination, include:

- Surface hydrology modifications;
- Drainage of the flood plain (lowered water tables);
- Dam construction;
- Modification of sedimentation processes;
- Land use changes;
- Invasive species;
- Canalization; and
- RGCP maintenance practices.

4.4.3 Current Environmental Conditions

A detailed discussion of the current environmental conditions can be found in previously published technical reports (Parsons 2000a, 2001b, and 2001c). The following section provides a summary of the vegetation communities, aquatic system, and overall habitat quality of the RGCP.

Vegetation Communities

The ROW under USIBWC jurisdiction within the RGCP encompass a total of 8,332 acres of land and 2,730 acres of aquatic habitat. Table 4-4 presents the land cover distribution of terrestrial and aquatic habitats. Terrestrial lands are classified as floodway, wetlands, and uplands. Floodway habitats correspond to the Rio Grande flood plain, and represent the areas most suitable for riparian environmental restoration. A detailed discussion of land cover classes and the classification process was presented in a separate technical report documenting the status of RGCP habitats (Parsons 2001b). The distribution of vegetation is presented by RMUs in Table 4-4.

Table 4-4 Current Habitat Distribution

Habitat Class	Acreage by River Management Unit							
	Entire Project	Upper Rincon	Lower Rincon	Seldon Canyon	Upper Mesilla	Las Cruces	Lower Mesilla	El Paso
River Miles:		105-90	89-70	69-63	62-50	49-40	40-20	19-0
TERRESTRIAL HABITAT								
Wetlands	177	54	51	2	15	9	35	11
Floodway	6,350	1,347	1,324	26	821	477	1,422	933
Uplands	1,805	1,641	164	0	0	0	0	0
Subtotal Terrestrial	*8,332*	*3,042*	*1,539*	*28*	*836*	*486*	*1,457*	*944*
AQUATIC HABITAT								
Open Water	2,514	260	523	250	181	213	644	443
Unconsolidated Shoreline	216	11	18	13	111	20	41	2
Subtotal Aquatic	*2,730*	*271*	*541*	*263*	*292*	*233*	*685*	*445*
TOTAL HABITAT								
Terrestrial Habitat	8,332	3,042	1,539	28	836	486	1,457	944
Aquatic Habitat	2,730	271	541	263	292	233	685	445
Total Acreage for RGCP	*11,062*	*3,313*	*2,080*	*291*	*1,128*	*719*	*2,142*	*1,389*

Periodic mowing maintains a large portion of the RGCP floodway in a disturbed, early successional state characterized by herbaceous vegetation and woody re-growth. The control of woody vegetation through mowing is a major O&M activity within the floodway and is conducted to reduce woody vegetation for flood control.

With regard to wildlife habitat quality, the majority of the RGCP lands can be characterized as below average (59 percent of the ROW) and poor quality (30 percent of the ROW). The remaining 11 percent of the ROW contains average quality habitats typically found in locations that offer relatively continuous vegetative cover and structure (shrublands, woodlands, and infrequently maintained areas). Riparian areas (salt cedar dominated or otherwise) offer the highest relative wildlife habitat quality due to structural diversity. However, vegetation within the floodway is dominated by herbaceous vegetation subjected to mowing and grazing where the habitat quality is characterized as below-average. A detailed discussion concerning habitat quality by land cover classes and RMU is found in the HEP and WHAP Surveys for Evaluation of Aquatic and Wildlife Habitat (Parsons 2001b).

Aquatic Community

Instream habitat within the RGCP is characterized as low diversity. There is very little pool/riffle structure, with the majority of the river classified as undifferentiated run. Instream cover, which provides essential habitat for different life stages of invertebrate and vertebrate life, is very limited. The river channel has little sinuosity, and little variation in velocity, except in the upper reaches of the RGCP. Sand and silt dominate the substrate. River banks are moderately stable to unstable. The Rio Grande between Caballo Dam and the City of El Paso currently supports a fish community of 22 recorded species, including channel catfish, white crappie, blue gill, common carp, river carpsucker, gizzard shad, black bullhead, flathead catfish, largemouth bass, green sunfish, and longear sunfish (Sublette and Hatch 1990). Aquatic habitat quality is discussed further in the HEP and WHAP Surveys for Evaluation of Aquatic and Wildlife Habitat (Parsons 2001b).

4.4.4 Opportunities and Constraints

Analysis of opportunities and constraints provides a means to simultaneously assess issues and develop realistic restoration goals. Without serious consideration of constraints, development of some environmental measures could result in alternatives with virtually no chance of acceptance or implementation. Opportunities and constraints were organized into three broad categories: fluvial process, aquatic habitat, and riparian corridor. The assessment of these opportunities and constraints is found in Table 4-5.

4.4.5 Restoration Goals and Associated Environmental Measures

Current guidelines on stream corridor restoration (Federal Interagency Stream Restoration Group 1998) emphasize the need to identify realistic goals as a key ingredient for restoration success. Those goals, which provide the framework for adaptive management, are developed as an integration of the ecological reference condition (desired future conditions), and social, political, and economic values.

Two main goals identified for RGCP restoration were to partially restore native riparian habitat --defined as the reestablishment of a riparian corridor and improvement in wildlife habitat-- and aquatic habitat improvement by partially restoring physical characteristics of the river and habitat diversification. A series of desired future conditions for the RGCP were associated with each goal and their components, as listed below.

Table 4-5 Assessment of Restoration Issues and Concepts Based on Opportunities and Constraints

Measure	Opportunities	Constraints
Fluvial Process		
Increase river sinuosity, provide for lateral migration, and increase channel width	A total of eight meanders were cut off during RGCP construction and are currently within the ROW. Extensive floodway ROW is found in the Rincon Valley and Upper Mesilla Valley.	Decreases in water delivery efficiencies would require compensation for water use. Several significant meanders were severed before project construction (i.e. Vinton cutoff) and are currently in private ownership and/or developed.
Mimic the natural hydrograph	Modeling of various flow releases from Caballo Dam shows opportunities for overbank flows throughout the Rincon Valley. In addition, periodic storm events in conjunction with irrigation flows occasionally (every 2-3 years) provide increases in flow rates during early spring.	Flows are tightly controlled by upstream dams, which release water primarily in response to irrigation demands. Water delivery regimes must convey normal irrigation flows to the EBID, EPCWID#1, and Mexico. Flow increases over irrigation rates can cause flooding in lands outside USIBWC jurisdiction (Seldon Canyon).
Create conditions for a connected river and floodway	The RGCP is over 105 miles in length and is characterized by a disconnected flood plain rarely extending beyond ROW. Hundred acres of floodway are located within the hydrologic flood plain and present opportunities for overbank flows.	The amount of sediment "nourishing" the Rio Grande has been greatly modified and has radically altered the current and potential river form. The narrow channel and incised banks reflect RGCP construction and maintenance practices, but more importantly the overriding influences of hydrologic modifications.
Aquatic Habitat		
Increase streambed diversity such a pools, riffles and backwaters	Multiple arroyos are present, and dredging is required. Most meanders cut during canalization are located within the RGCP.	Infrastructure such as bridges (28), irrigation flumes, siphons, and utilities must be maintained. Use of artificial structures have shown little environmental benefit.
Diversify river/terrestrial edge	Modifications to current vegetation control (mowing and grazing leases) would have positive impacts to wildlife habitat thorough much of the floodway.	Potential deficiencies in the levee system and need to control salt cedar limit allowable vegetation growth, particularly in urban areas.
Enhance surface water quality	The majority of over 1,891 square miles of contributing watershed are managed by federal and state government.	The vast majority of the contributing watershed is not controlled by the USIBWC.
Riparian Corridor		
Increase vegetative structural diversity (patch and edge habitat)	Modifications to current vegetation control (mowing) would have positive impacts to wildlife habitat thorough much of the floodway. In addition, 3,325 ac of ROW are leased for grazing.	Flood control must be maintained throughout the RGCP, requiring floodway maintenance activities. Potential levee deficiencies in urban areas represent a significant constraint to modifications in floodway management.
Increase riparian corridor width (Buffer zone)	Lands adjacent to RGCP are available for conservation easements or interagency cooperative management.	RGCP adjacent lands are mostly cropped or urbanized. Landowners willingness to participate in a conservation easements program is unknown.
Improve upland and flood plain connectivity	35 miles of floodway and uplands are adjacent to lands owned by other agencies.	Land use adjacent to the ROW corridor consists of only 18% government owned.
Increase native woody vegetation component (cottonwood-willows)	Land within the ROW cover 8,332 acres, the majority of which (89%) is considered below average to poor quality habitat.	Exotic species are prevalent throughout the RGCP and complete eradication is not feasible.
Increase amount of riparian habitat	More than 350 acres of floodway lands are within hydrologic flood plain.	Potential deficiencies in the levee system limit allowable vegetation growth.
Maintain a sustainable native riparian community	Ongoing riparian vegetation recruitment in El Paso (Sunland Park) suggests potential for sustainment.	Requires acquisition of water and/or agreements with New Mexico and Texas irrigation districts.

Goal 1: Riparian Habitat Improvement

Component A. Restore Native Riparian Habitat

- Increase native woody vegetation (cottonwood community) component;
- Increase amount of riparian habitat; and
- Maintain a sustainable native riparian community.

Component B. Improve Wildlife Habitat

- Increase vegetative structural diversity (patch and edge habitat);
- Increase riparian corridor width (buffer zone); and
- Improve upland and flood plain connectivity.

Goal 2: Aquatic Habitat Improvement

Component A. Diversify Aquatic Habitat

- Increase streambed diversity such as pools, riffles, and backwaters;
- Diversify river/terrestrial edge; and
- Enhance surface water quality.

Component B. Restore Physical Characteristics of the River

- Increase river sinuosity, provide for lateral migration, and increase channel width;
- Mimic the natural hydrograph; and
- Create conditions for a connected river and floodway.

Once desired conditions were identified, the applicability of environmental measures was evaluated for each restoration goal and its components. Tables 4-6 and 4-7 illustrate how environmental measures align with restoration goals.

Environmental Projects

The application of environmental measures within the RGCP resulted in identification of specific projects. Several criteria, listed in Table 4-8, were used to determine the geographic area, site-specific location, and extent of environmental measures. Table 4-9 summarizes the extent and geographic distribution of areas identified for potential application of environmental measures.

Table 4-6 Environmental Measures Associated with Goal 1 – Restore Native Riparian Habitat

Desired Future Condition	Environmental Measures
A. Restore Native Riparian Habitat	
Increase amount of riparian habitat	a) Plant woody native vegetation b) Bank shavedowns to promote natural regeneration c) Seasonal peak flows to promote natural regeneration d) Conservation easement e) Modify grazing f) Modified grassland management in floodway
Increase native woody vegetation component	a) Bosque enhancement b) Plant woody native vegetation c) Bank shavedowns to promote natural regeneration d) Seasonal peak flows to promote natural regeneration e) Modified grassland management in floodway
Maintain a sustainable native riparian community (Connected river and floodway)	a) Bank shavedowns to promote natural regeneration b) Seasonal peak flows to promote natural regeneration c) Modify grazing
B. Improve Wildlife Habitat	
Increased vegetative structural and species diversity	a) Modified grassland management in floodway b) Plant woody native vegetation c) Bank shavedowns to promote natural regeneration d) Seasonal peak flows to promote natural regeneration
Increase riparian corridor width	a) Conservation easements
Improved upland and flood plain connectivity	a) Modified grassland management in floodway b) Modify grazing c) Conservation easements

Table 4-7 Environmental Measures Associated with Goal 2 – Aquatic Habitat Restoration

Desired Future Condition	Environmental Measures
A. Aquatic Habitat Improvement	
Increase in streambed diversity such as pools, riffles and backwaters	a) Open former meanders b) Modify dredging at arroyos by creating embayments
Diversified river/terrestrial edge	a) Modified grassland management in floodway b) Modify grazing
Improved water quality	a) Modify grazing b) Conservation easements c) Bank shavedowns d) Open meanders
B. Restore River Physical Characteristics	
Increase in river sinuosity, lateral migration, channel width	a) Open former meanders b) Bank shavedowns c) Seasonal peak flows
Mimic the natural hydrograph	a) Seasonal peak flows

Table 4-8 Application Criteria for Environmental Measures

Restoration Measures	Criteria Used
Open former meanders	Locations based on historical maps and topographic data developed from USACE elevation survey. Meanders inside the ROW and within the hydrologic flood plain were considered as candidates for reopening. In situations involving extensive ROW width, channels outside the hydrologic flood plain were selected. Not conducted in areas of levee deficiencies (less than 3 feet of freeboard).
Bank shavedowns	Located within the hydrologic flood plain. Hydrologic flood plain based on HEC-RAS modeling results and GIS analyses. Not conducted in areas of levee deficiencies (overtopping or within 2 feet of freeboard).
Seasonal peak flows	Locations largely the same as bank shavedowns (slightly larger extent than bank shavedown based on hydrologic flood plain). Seasonal peak flows represent an alternative and/or complementary method to inundate the hydrologic flood plain based on a peak flow of 5000 cfs from Caballo dam.
Conservation easements	Adjacent undeveloped sites to the ROW which provided significant benefit for wildlife habitat and/or corridor expansion along the RGCP.
Modify dredging at arroyos by creating embayments	All major arroyos entering the RGCP.
Modify grazing practices	All upland habitat and floodways with potential for upland/river connectivity (particularly Upper Mesilla and Rincon Valley). Grazing considered a tool for vegetation control in flood prone areas of ROW such as El Paso.
Enhance existing bosques	Suitable bosques located within the hydrologic flood plain.
Plant woody native vegetation	Located within the hydrologic flood plain. Hydrologic flood plain based on HEC-RAS modeling results and GIS analyses. Not conducted in areas of levee deficiencies (overtopping or within 2 feet of freeboard) in developed areas.
Modified grassland management in floodway	Used to “connect” riparian restoration locations, connect uplands with river flood plain, wide areas in floodway and provide buffers around sites. Not conducted in areas of levee deficiencies (overtopping or within 2 feet of freeboard) in developed areas. This measure also was used to expanded existing green zones.

Table 4-9 Summary of Areas Identified for Potential Application of Environmental Measures

	ACREAGE BY RIVER MANAGEMENT UNIT							
Environmental Measure	**Upper Rincon**	**Lower Rincon**	**Seldon Canyon**	**Upper Mesilla**	**Las Cruces**	**Lower Mesilla**	**El Paso**	**Entire Project**
Modified O&M and Flood Control Improvement Alternative								
Modify grazing in uplands and floodway	1641	743		1099			69	**3552**
Integrated USIBWC Land Management Alternative								
Modified grassland management	639	611		22	301	68		**1641**
Modify grazing in uplands and floodway	1911	473		638	136	256	138	**3552**
Bank shave downs to promote natural regeneration	93	34						**127**
Existing bosque enhancement	3	0						**3**
Plant woody native vegetation	121	26		20	50			**217**
Targeted River Restoration Alternative								
Seasonal peak flows to promote natural regeneration	214	302						**516**
Modified grassland management	639	611		22	301	68		**1641**
Conservation easements		536	808	28	202	27	44	**1645**
Modify grazing in uplands and floodway	1911	473		638	136	256	138	**3552**
Open former meanders	122			19.5				**142**
Modify dredging at arroyos by creating embayments	2.6	2.6						**5**
Existing bosque enhancement	2.5							**3**
Plant woody native vegetation	27.3	26			50	86		**189**